(12) EUROPEAN PATENT APPLICATION

(72) Inventors:
• Caronia, Paul Joseph
  Annandale (08801), New Jersey (US)
• Shurott, Salvatore Frans
  South River (08885), New Jersey (US)

(74) Representative: Allard, Susan Joyce et al
BOULT, WADE & TENNANT
27 Furnival Street
London EC4A 1PQ (GB)

(54) A process for extrusion

(57) A process for the co-extrusion of an inner layer around a conductive medium and an outer layer around the inner layer comprising:

(i) introducing into an extruder adapted for profile co-extrusion, a conductive medium; an inner layer formulation comprising a homogeneous polyethylene having a polydispersity in the range of about 1.5 to about 3.5 and an essentially uniform comonomer distribution, and an organic peroxide; and an outer layer formulation comprising (a) a copolymer of ethylene and an unsaturated ester; (b) a polyethylene having a polydispersity greater than about 4.0 and a density of at least 0.916 gram per cubic centimeter, said polymer made by a high pressure process; or (c) a heterogeneous copolymer of ethylene and one or more alpha-olefins having a density of less than 0.916 gram per cubic centimeter, a melt index of at least about 4 grams per 10 minutes, and a polydispersity greater than about 4.0, and, optionally, an organic peroxide; and

(ii) co-extruding said formulations at a temperature no higher than about 160 degrees C.

EP 0 743 161 A2

Description

Technical Field

5   This invention relates to a process for co-extrusion over an electrical conductor or communications medium in which the extrudate is essentially free of melt fracture.

Background Information

10   Polyethylene, during processing operations such as extrusion, is known to experience a phenomenon described as melt fracture in which, upon exiting the extruder die, the extrudate has a highly irregular surface. The irregular surface is rough, and it does not have a consistent surface for fabricating a quality finished article or for producing an aesthetically pleasing article. Linear polyethylenes such as LLDPE (linear low density polyethylene) and VLDPE (very low density polyethylene), due to an inherent molecular structure/melt rheology characteristic, are highly susceptible
15   to melt fracture while highly branched polyethylene such as LDPE (low density polyethylene) is significantly less prone to melt fracture. With high molecular weight (low melt index), narrow molecular weight distribution, narrow (uniform) comonomer distribution linear polyethylene, the melt fracture phenomenon is especially severe under relatively low temperature extrusion conditions such as temperatures below 160 degrees C, ranging as low as about 100 degrees C.
      Conventional techniques for the elimination of melt fracture are to raise the process temperature thus reducing
20   the polymer's viscosity, which results in a corresponding lower shear strain at the die; to decrease the output rate thus decreasing the shear rate and corresponding shear strain at the die; or to increase the die shear rate thus increasing the polymer's viscous energy generation to raise the localized melt temperature for an effect similar to raising the process temperature. These techniques reduce the viscosity of the polymer and the resulting melt fracture. However, there are deficiencies in these techniques that make them unacceptable for processing materials under low temperature
25   processing conditions, i.e., temperatures below 160 degrees C.
      The requirement for processing temperatures of less than 160 degrees C is desirable when extruding a resin formulation containing an organic peroxide, a thermally sensitive additive. When extruding a polyethylene formulation containing an organic peroxide, raising the process temperature is not a desired option to eliminate melt fracture in view of the problem of scorch, i.e., premature crosslinking caused by the decomposition of the organic peroxide. De-
30   creasing the output rate is also not desirable because it increases the cost of manufacturing the extrudate product. Finally, increasing the die shear rate is similar in effect to raising the melt temperature with the attendant scorch.
      Another approach to addressing the melt fracture phenomenon is to redesign the process equipment; however, this involves designing equipment for a specific molecular weight resin which limits the usefulness of the equipment, and, of course, raises the cost. Incorporating processing aid additives is another approach, but this is expensive and
35   may affect other product properties. Blending a lower molecular weight polymer with a relatively high molecular weight polymer has the disadvantage that it typically results in a product with properties inferior to the high molecular weight product's properties.
      Co-extrusion methods have also been employed to overcome melt fracture, but these methods have been generally applied to tubular blown film processes rather than extrusion around wire or glass fibers, for example. And these blown
40   film processes have been conducted at temperatures considerably higher than 160 degrees C with resin formulations, which do not include peroxides. Further, the polyethylene resins used in these blown film processes have been of the heterogeneous type, which are not as susceptible to the melt fracture phenomenon.

Disclosure of the Invention
45

      An object of this invention, therefore, is to provide a process for the extrusion of a homogeneous polyethylene formulation containing an organic peroxide around a conductive medium wherein the extrudate is essentially free of melt fracture. Other objects and advantages will become apparent hereinafter.
      According to the invention, a process has been discovered, which meets the above object.
50   The process is one for the co-extrusion of an inner layer around a conductive medium and an outer layer around the inner layer comprising:

      (i) introducing into an extruder adapted for profile co-extrusion, a conductive medium; an inner layer formulation comprising a homogeneous polyethylene having a polydispersity in the range of about 1.5 to about 3.5 and an
55   essentially uniform comonomer distribution, and an organic peroxide; and an outer layer formulation comprising (a) a copolymer of ethylene and an unsaturated ester; (b) a polyethylene having a polydispersity greater than about 4.0 and a density of at least 0.916 gram per cubic centimeter, said polymer made by a high pressure process; or (c) a copolymer of ethylene and one or more alpha-olefins having a density of less than 0.916 gram per cubic

centimeter, a melt index of at least about 4 grams per 10 minutes, and a polydispersity greater than about 4.0, and, optionally, an organic peroxide; and

(ii) co-extruding said formulations at a temperature no higher than about 160 degrees C.

Description of the Preferred Embodiment(s)

A profile extrusion process is one in which an extrudate having a structural profile such as wire insulation or cable jacketing is prepared. A structural profile typically involves a shaped viscous melt exiting a forming die followed by cooling. The conductive medium can be an electrical conductor, a core made up of two or more electrical conductors, or a fiber optic communications medium made up of one or more glass fibers formed into a glass core. The extruder is described below. The term "extruder", in the context of this specification, means one or more extruders with the attendant apparatus required for the co-extrusion of polymer formulations around a conductive medium such as a wire or glass fiber.

The inner layer extruded around the conductive medium is a homogeneous polyethylene formulation. The thickness of the inner layer is generally in the range of about 30 to about 300 mils. Homogeneous polyethylenes are copolymers of ethylene, one or more alpha-olefins, and, optionally, a diene. The alpha-olefins can have 3 to 12 carbon atoms, and preferably have 3 to 8 carbon atoms. Examples of the alpha-olefins are propylene, 1-butene, 1-hexene, 4-methyl-1-pentene, and 1-octene. The dienes can have about 4 to 20 carbon atoms. Examples of the dienes are 1,4-pentadiene, 1,3-hexadiene, 1,5-hexadiene, 1,4-octadiene, 1,4-hexadiene, dicyclopentadiene, and ethylidene norbornene. As noted above, these homogeneous polyethylenes have a polydispersity (Mw/Mn) in the range of about 1.5 to about 3.5 and an essentially uniform comonomer distribution. The homogeneous polyethylenes are characterized by single and relatively low DSC melting points. Heterogeneous polyethylenes (the more common of the two), on the other hand, have a polydispersity (Mw/Mn) greater than 3.5 and do not have a uniform comonomer distribution. Mw is defined as weight average molecular weight and Mn is defined as number average molecular weight. The homogeneous polyethylenes can have a density in the range of 0.860 to 0.930 gram per cubic centimeter, and preferably have a density in the range of 0.870 to about 0.920 gram per cubic centimeter. They also can have a melt index in the range of about 0.5 to about 30 grams per 10 minutes, and preferably have a melt index in the range of about 0.5 to about 5 grams per 10 minutes.

Homogeneous polyethylenes can be prepared, for example, with vanadium based catalysts such as those described in United States Patents 5,332,793 and 5,342,907, and they can also be prepared with single site metallocene catalysts such as those described in United States Patents 4,937,299 and 5,317,036.

The outer layer surrounding the inner layer is a formulation containing one of three different polymers. The first polymer (a) is an ethylene polymer prepared by conventional high pressure processes. These polymers are highly branched with a good deal of long chain branching. The ethylene polymer can be a copolymer of ethylene and an unsaturated ester such as vinyl acetate, ethyl acrylate, methyl acrylate, methyl methacrylate, t-butyl acrylate, n-butyl acrylate, n-butyl methacrylate, 2-ethylhexyl acrylate, and other alkyl acrylates. The unsaturated ester can have 4 to 20 carbon atoms, preferably no more than 12 carbon atoms. The unsaturated ester can be present in the copolymer in an amount of about 5 to about 40 percent by weight, and preferably 10 to about 35 percent by weight, based on the weight of the copolymer. The density of the copolymer can be in the range of 0.916 to 0.940 gram per cubic centimeter, and is preferably in the range of 0.925 to 0.935 gram per cubic centimeter. The melt index can be in the range of about 5 to about 100 grams per 10 minutes, and is preferably in the range of about 8 to about 70 grams per 10 minutes.

The outer layer can also be made up of a formulation containing polymer (b), a high pressure polyethylene, usually a homopolymer of ethylene, prepared for example by the high pressure process described in Introduction to Polymer Chemistry, Stille, Wiley and Sons, New York, 1962, at pages 149 to 151. The density of the homopolymer can be in the range of 0.916 to 0.930 gram per cubic centimeter, and is preferably in the range of 0.920 to 0.928 gram per cubic centimeter. The melt index can be in the range of about 1 to about 10 grams per 10 minutes, and is preferably in the range of about 2 to about 5 grams per 10 minutes. Melt index is determined in accordance with ASTM D-1238, Condition E, measured at 190 degrees C.

Finally, the outer layer can be made up of a formulation containing polymer (c), which can be referred to as very low density polyethylene (VLDPE). This polymer has a density of less than 0.916 gram per cubic centimeter. The density can be as low as 0.860 gram per cubic centimeter. The VLDPE can be made by conventional low pressure processes such as those mentioned in United States patents 4,302,565 and 4,508,842. VLDPE is a copolymer of ethylene and one or more alpha-olefins, each having 3 to 12 carbon atoms, and preferably 3 to 8 carbon atoms. Examples of the alpha-olefins are propylene, 1-butene, 1-hexene, 4-methyl-1-pentene, and 1-octene.

The polydispersity (Mw/Mn) of the outer layer polymer can be at least about 4, and is preferably in the range of about 4.5 to about 10.

The outer layer is generally at least about 5 mils in thickness, and for wire and cable applications is preferably at least about 15 mils in thickness. The upper limit of thickness is just a matter of economics, the lower the upper limit, the more economical it is to provide same.

Conventional additives, which can be introduced into either formulation, are exemplified by antioxidants, coupling agents, ultraviolet absorbers or stabilizers, antistatic agents, pigments, dyes, nucleating agents, reinforcing fillers or polymer additives, resistivity modifiers such as carbon black, slip agents, plasticizers, processing aids, lubricants, viscosity control agents, tackifiers, anti-blocking agents, surfactants, extender oils, metal deactivators, voltage stabilizers,
5   flame retardant fillers and additives, crosslinking boosters and catalysts, and smoke suppressants. Fillers and additives can be added to the outer layer formulation in amounts ranging from less than about 0.1 to more than about 200 parts by weight for each 100 parts by weight of the base resin. Fillers and additives can be added to the inner layer formulation in amounts ranging from less than about 0.1 to no more than about 5 parts by weight for each 100 parts by weight of base resin.

10   Examples of antioxidants are: hindered phenols such as tetrakis[methylene(3,5-di-tert- butyl-4-hydroxyhydrocinnamate)]methane, bis[(beta-(3,5-ditert-butyl-4-hydroxybenzyl)methylcarboxyethyl)]sulphide, 4,4'-thiobis(2-methyl-6-tert-butylphenol), 4,4'-thiobis(2-tert-butyl-5-methylphenol), 2,2'-thiobis(4-methyl-6-tert-butylphenol), and thiodiethylene bis(3,5-di-tert-butyl-4-hydroxy)hydrocinnamate; phosphites and phosphonites such as tris(2,4-di-tert-butylphenyl) phosphite and di-tert-butylphenyl-phosphonite; thio compounds such as dilaurylthiodipropionate, dimyristylthiodipro-
15   pionate, and distearylthiodipropionate; various siloxanes; and various amines such as polymerized 2,2,4-trimethyl-1,2-dihydroquinoline. Antioxidants can be used in amounts of about 0.1 to about 5 parts by weight per 100 parts by weight of polyethylene.

As noted above, the low temperature additives, which create the problem of scorch at extrusion temperatures above about 160 degrees C, are organic peroxides. These organic peroxides can be used to crosslink the polyethylene
20   resins. They are one component of the inner layer formulation and are an optional component of the outer layer formulation. The organic peroxides are conventional and are used in conventional amounts. Examples of organic peroxides are as follows (the decomposition temperature in degrees C is given in parentheses): succinic acid peroxide (110), benzoyl peroxide (110), t-butyl peroxy-2-ethylhexanoate (113), p-chlorobenzoyl peroxide (115), t-butyl peroxyisobutyrate (115), t-butyl peroxyisopropyl carbonate (135), t-butyl peroxylaurate (140), 2,5-dimethyl-2,5-di(benzoyl peroxy)
25   hexane (140), t-butyl peroxyacetate (140), di-t-butyl peroxyphthalate (140), t-butyl peroxymaleate (140), cyclohexanone peroxide (145), t-butyl peroxybenzoate (145), dicumyl peroxide (150), 2,5-dimethyl- 2,5-di(t-butyl peroxy)hexane-3 (155), t-butyl cumyl peroxide (155), t-butyl hydroperoxide (158), and di-t-butyl peroxide (160). Dicumyl peroxide is preferred.

The co-extrudate, which is the product of the process of this invention, can be prepared in various types of extruders
30   provided that they are adapted for co-extrusion. Compounding can be effected in the extruder or prior to extrusion in a conventional mixer such as a Brabender™ mixer or a Banbury™ mixer. Various extruders and processes for profile extrusion are described in United States patents 4,814,135; 4,857,600; 5,076,988; and 5,153,382. All types of single screw and twin screw extruders and polymer melt pumps and extrusion processes will generally be suitable in effecting the process of this invention. A typical extruder, commonly referred to as a fabrication extruder will have a solids feed
35   hopper at its upstream end and a melt forming die at its downstream end. The hopper feeds unfluxed plastics into the feed section of a barrel containing the processing screw(s) that flux and ultimately pump the plastic melt through the forming die. At the downstream end, between the end of the screw and the die, there is often a screen pack and a breaker plate. Fabrication extruders typically accomplish the mechanisms of solids conveying and compression, plastics fluxing, melt mixing and melt pumping although some two stage configurations use a separate melt fed extruder
40   or melt pump equipment for the melt pumping mechanism. Extruder barrels are equipped with barrel heating and cooling features for startup and improved steady state temperature control. Modern equipment usually incorporates multiple heating/cooling zones starting at the rear feed zone and segmenting the barrel and downstream shaping die. The length to diameter ratio of each barrel is in the range of about 15:1 to about 30:1. In a wire coating process, after passing through the breaker plate, the extrudate is pumped through a melt flow channel into a crosshead that reorients
45   the polymer flow typically by 90 degrees such that it is directed to uniformly coat the conductor. In a wire coating extrusion process in which multiple material layers are applied to the conductor, the molten polymer from each extruder is independently pumped into a crosshead that is designed to coat the wire or conductor such that the different material layers are distinct, i.e., the material layers are not mixed in the crosshead. The multiple layer crosshead can be designed such that the multiple material layers coat the conductor simultaneously or in a discrete manner. In wire coating appli-
50   cations where the material is crosslinked after extrusion, the die of the crosshead feeds directly into a heating zone, and this zone can be maintained at a temperature in the range of about 145°C to about 455°C, and preferably in the range of about 200°C to about 400°C. These temperature ranges cover steam cure vulcanization processes that typically operate at around 204°C and dry cure vulcanization processes that typically operate at around 400°C.

The advantages of the invention lie in the essential elimination of melt fracture in the inner layer even though the
55   co-extrusion process is run at temperatures of less than about 160 degrees C and the inner layer formulation contains a narrow molecular weight distribution and essentially uniform comonomer distribution (homogeneous) polyethylene. Further, where a strippable outer layer is provided, removal or stripping of the outer layer leaves an inner layer, which becomes the outer layer, with essentially no melt fracture.

4

The patents mentioned in this specification are incorporated by reference herein.

The invention is illustrated by the following examples.

Examples 1 to 39

5

The apparatus used in the examples and its operation are described as follows. In those examples where there is only a single layer, the inner layer extruder is used, and the additional apparatus, which is necessary to effect the co-extrusion is not used.

10 The extruder used for extruding the inner layer is a 2.5 inch, 20:1 L/D (length to diameter) single screw plasticating extruder manufactured by John Royle Company. It contains within its barrel a short lead polyethylene screw with a Maddock™ mixing section for plasticating the polymer. The extruder used for extruding the outer layer is a 1.5 inch, 24:1 L/D single screw plasticating extruder manufactured by Sterling Company. This extruder also contains within its barrel a polyethylene metering screw for plasticating the polymer. The molten polymers from each extruder are fed into a dual layer wire coating crosshead manufactured by Canterbury Engineering Company. A wire coating line in

15 which #14 AWG (American Wire Guide) solid copper wire having a diameter of 0.064 inch is taken off a shipping reel by a wire payoff through a wire metering capstan through the dual layer wire coating crosshead in which the wire is coated with molten polymer. The crosshead utilizes a guider tip with a hole diameter of 0.067 inch for guiding the wire into contact with the molten polymer coming from the 2.5 inch extruder followed by contact with the molten polymer from the 1.5 inch extruder. The wire, now coated with inner and outer layers of polymer, is drawn through a die with

20 an opening of 0.260 inch. The polymer coated wire is then drawn through a downstream vulcanization tube and water bath by a pullout capstan. Between the water bath and the capstan, a laser micrometer is positioned to measure the coated wire's outside diameter.

Melt fracture is determined by visually examining the coated wire. Each coated wire is given a value from 1 to 9 with the value 1 being the worst case of melt fracture and the value 9 representing essentially no melt fracture as follows:

25

1 = severely gross
2 = gross
3 = gross shark skin
4 = severe shark skin
30 5 = shark skin
6 = rough surface
7 = slightly rough surface
8 = minor imperfection, but acceptable
9 = essentially no melt fracture

35

Components used in the examples:

1. Polymer A is a homogeneous copolymer of ethylene and 1-octene wherein the 1-octene is present in an amount of 24 percent by weight based on the weight of the polymer. The polymer has a melt index of 1 gram per 10
40 minutes ; a density of 0.87 gram per cubic centimeter; an Mw/Mn of 2; an essentially uniform comonomer distribution; and is prepared with a metallocene catalyst.

2. Polymer B is a homogeneous copolymer of ethylene and 1-octene wherein the 1-octene is present in an amount of 24 percent by weight based on the weight of the polymer. The polymer has a melt index of 5 grams per 10
45 minutes; a density of 0.87 gram per cubic centimeter; an Mw/Mn of 2; an essentially uniform comonomer distribution; and is prepared with a metallocene catalyst.

3. Polymer C is a heterogeneous copolymer of ethylene and 1-hexene wherein the 1-hexene is present in an amount of 16 to 20 percent by weight based on the weight of the polymer. The polymer has a melt index of 4 grams
50 per 10 minutes ; a density of 0.905 gram per cubic centimeter; an Mw/Mn of 4.5; and is prepared with a magnesium/titanium catalyst.

4. Polymer D is a homopolymer of ethylene prepared by a high pressure process. The polymer has a melt index of 2 grams per 10 minutes ; a density of 0. 923 gram per cubic centimeter; an Mw/Mn of 5.2.

55

5. Polymer E is a copolymer of ethylene and ethyl acrylate wherein the ethyl acrylate is present in an amount of 15 to 25 percent by weight based on the weight of the copolymer. It is prepared by a high pressure process. The polymer has a melt index of 20 grams per 10 minutes.

6. Polymer F is a copolymer of ethylene and vinyl acetate wherein the vinyl acetate is present in an amount of 28 to 38 percent by weight based on the weight of the copolymer. It is prepared by a high pressure process. The polymer has a melt index of 35 grams per 10 minutes.

7. Formulation A is a melt blended mixture of 100 parts by weight Polymer A; 0.18 part by weight antioxidant A; 0.18 part by weight DSTDP; and 1.8 parts by weight dicumyl peroxide.

8. Formulation C is a melt blended mixture of 100 parts by weight Polymer C; 0.35 part by weight antioxidant A; 0.35 part by weight DSTDP; and 1.8 parts by weight dicumyl peroxide.

9. Formulation D is a melt blended mixture of 100 parts by weight Polymer D; 0.18 part by weight antioxidant A; and 0.18 part by weight DSTDP.

10. Formulation E is a melt blended mixture of 100 parts by weight Polymer E; 30+ parts by weight conductive carbon black; antioxidant B; and dicumyl peroxide.

11. Formulation F is a melt blended mixture of 100 parts by weight Polymer F; 20+ parts by weight conductive carbon black; antioxidant B; and dicumyl peroxide. It is designed to have a low adhesion to polyethylene such that it can easily be removed from a polyethylene inner layer.

12. Processing Aid A is a copolymer of vinylidene fluoride and hexafluoropropylene.

13. Processing Aid B is a mixture containing 80 percent by weight Processing Aid A and 20 percent by weight polyethylene.

14. DSTDP is distearylthiodipropionate.

15. Antioxidant A is thiodiethylene bis(3,5-di-tert-butyl-4-hydroxyhydrocinnamate).

16. Antioxidant B is an Agerite™ MA acetone-aniline condensation product.

The variables and the results are set forth in the following Table. The temperature range for each extruder reflects the high and low temperatures of the temperatures measured at each of the four heating zones, the flange, the head, and the die.

Note: where the polymer is mentioned instead of a formulation, it will be understood that the polymer is being used in the "as received" condition from the manufacturer. This means that the polymer contains calcium stearate and may contain other additives, usually stabilizers. The total amount of additives, however, is no greater than about 1 part per 100 parts of polymer. In any case, 1.8 parts by weight of dicumyl peroxide per 100 parts by weight polymer is present.

Table

example	1	2	3	4	5	6	7	8	9	10
single layer polymer	A	A	A	A	A	A	A	A	A	A
single layer operating conditions:										
temperature range (°C)	123 to 143	123 to 142	123 to 142	123 to 141	112 to 130	112 to 130	112 to 128	112 to 130	99 to 119	99 to 120
revolutions per minute	7	14	14	14	7	14	14	14	7	14
feet per minute	15	33	20	10	15	33	20	10	15	33

Table (continued)

example	1	2	3	4	5	6	7	8	9	10
melt temperature (°C)	150	154	156	156	138	141	143	144	126	131
extrudate wall thickness (inch):										
minimum	0.070	0.069	0.098	0.145	0.062	0.067	0.105	0.146	0.078	0.058
maximum	0.083	0.091	0.103	0.153	0.088	0.094	0.116	0.156	0.156	0.103
melt fracture:										
single layer	2	1	4	5	1	1	3	5	1	1

Table (continued)

example	11	12	13	14	15	16	17	18	19	20
single or inner layer polymer (*) or formulation (**)	A*	A*	A*	A*	A*	A**	A**	A*	A*	A*
single or inner layer operating conditions:										
temperature range (°C)	99 to 118	99 to 119	99 to 118	99 to 118	99 to 118	104 to 118	104 to 118	99 to 119	100 to 120	99 to 119
revolutions per minute	14	14	14	14	14	13	13	15	15	14

Table (continued)

example	11	12	13	14	15	16	17	18	19	20
feet per minute	20	10	33	33	33	27	27	33	33	33
melt temperature (°C)	133	133	132	132	131	134	134	137	137	134
minimum	0.098	0.145	0.078	0.086	0.091	---	---	---	---	---
maximum	0.113	0.158	0.083	0.088	0.094	---	---	---	---	---
outer layer operating conditions:	---	---				---		---		
temperature range (°C)			99 to 118	99 to 118	99 to 119		107 to 116		100 to 115	100 to 116

Table (continued)

example	11	12	13	14	15	16	17	18	19	20
revolutions per minute	---	---	12	18	24	---	18	---	24	20
melt temperature (°C)	---	---	120	122	123	---	121	---	123	126
outer layer wall(mils)	---	---	15 to 16	22 to 24	33 to 36	---	---	---	---	---
melt fracture: single or inner layer	1	1	9	9	9	1	---	1	---	1
outer layer (composite)	---	---	9	9	9	1	9	---	9	---

Table (continued)

example	21	22	23	24	25	26	27	28	29	30
single layer polymer	A	A	A	A	A	B	B	B	B	B
processing aid	---	---	---	B (500 ppm A)	B (500 ppm A)	---	---	---	---	---
single layer operating conditions:										
temperature range (°C)	99 to 119	99 to 119	99 to 118	99 to 118	99 to 118	99 to 119	99 to 119	99 to 119	99 to 119	99 to 118
revolutions per minute	14	14	14	14	16	18	24	30	12	13
feet per minute	33	20	10	10	33	33	33	33	33	33

Table (continued)

example	21	22	23	24	25	26	27	28	29	30
melt temperature (°C)	134	136	136	137	137	132	135	138	129	129
extrudate wall thickness (inch):										
minimum	0.058	0.105	0.153	0.153	0.094	0.083	0.097	0.111	0.059	0.065
maximum	0.123	0.123	0.168	0.166	0.113	0.084	0.100	0.116	0.064	0.069
melt fracture:										
single layer	1	2	5	5	1	5	5	5	6	6

Table (continued)

example	31	32	33	34	35	36	37	38	39
single or inner layer polymer (*) or formulation (**)	B*	B*	B*	B*	B*	C**	C**	C**	C**
processing aid	---	B (500 ppm A)		B (500 ppm A)	---	---	---	---	---
single or inner layer operating conditions:									
temperature range (°C)	99 to 118	99 to 118	99 to 119	99 to 119	99 to 119	116 to 127	116 to 127	116 to 124	116 to 124

14

Table (continued)

example	31	32	33	34	35	36	37	38	39
revolutions per minute	14	14	14	14	14	12	12	12	12
feet per minute	33	33	20	10	33	33	33	33	33
melt temperature (°C)	129	129	129	129	127	131	131	131	131
extrudate wall thickness (inch):									
minimum	0.069	0.067	0.094	0.128	0.090	0.078	0.101	0.088	0.096
maximum	0.074	0.072	0.096	0.136	0.093	0.078	0.077	---	---

Table (continued)

example	31	32	33	34	35	36	37	38	39
outer layer formulation	---	---	---	---	F	---	F	---	D
outer layer operating conditions:									
temperature range (°C)	---	---	---	---	99 to 119	---	93 to 116	---	107 to 118
revolutions per minute	---	---	---	---	24	---	22	---	24
melt temperature (°C)	---	---	---	---	127	---	123	---	121

Table (continued)

example	31	32	33	34	35	36	37	38	39
melt fracture:									
single inner layer	6	6	7	8	9	9	---	9	---
outer layer (composite)	---	----	----	----	9	---	9	----	9

Notes to Table:

1. Examples 1 to 12 attempt to avoid melt fracture with respect to Polymer A by varying process conditions such as temperatures, revolutions per minute, and feet per minute, while operating below 160 degrees C, without success.

2. Examples 13 to 15 co-extrude Formulation F over Polymer A under conditions similar to examples 1 to 12. This essentially eliminates melt fracture both in the inner layer and the outer layer (composite).

3. Examples 16 and 17 use the same inner layer conditions. In example 17, however, there is a co-extrusion of Formulation D over Formulation A. Example 16 results in severely gross melt fracture while the outer layer (or composite) of example 17 is essentially free of melt fracture.

17

4.   Example 18 is similar in result to examples 1 to 12 and 16.   Example 19 is a co-extrusion of Formulation E over Polymer A, and the outer layer (or composite) is essentially free of melt fracture.

5.   Example 20 is a co-extrusion of Polymer A over Polymer A.   The result is severely gross melt fracture.

6.   Examples 21 to 23 are similar in result to examples 1 to 12, 16, and 18.   Examples 24 and 25 use a processing aid with little or no improvement.

7.   Examples 26 to 30 use Polymer B, which is similar to Polymer A, but with a higher melt index.   There is some improvement in melt fracture, but the result is still far from commercial acceptability.

8.   Example 31 is similar in result to examples 26 to 30.   Examples 32 to 34 use processing aids with some improvement with example 34 showing minor, but acceptable melt fracture.   Example 35 is a co-extrusion of Formulation F over Polymer B, and there is essentially no melt fracture in the inner or outer layers.

9.   Examples 36 and 38 use heterogeneous Polymer C in Formulation C without co-extrusion and the result is essentially no melt fracture.   Example 37 co-extrudes Formulation F over Formulation C and example 39 co-extrudes Formulation D over Formulation C.   The result is, again, essentially no melt fracture.

10.   In examples 13 to 15, 17, 19, 20, 35, 37, and 39 where outer layer temperature ranges are given, flange, head, and die temperatures are not recorded.

Claims

1. A process for the co-extrusion of an inner layer around a conductive medium and an outer layer around the inner layer comprising:

   (i) introducing into an extruder adapted for profile co-extrusion, a conductive medium; an inner layer formulation comprising a homogeneous polyethylene having a polydispersity in the range of from 1.5 to 3.5 and an essentially uniform comonomer distribution, and an organic peroxide; and an outer layer formulation comprising (a) a copolymer of ethylene and an unsaturated ester; (b) a polyethylene having a polydispersity greater than about 4.0 and a density of at least 0.916 gram per cubic centimeter, said polymer made by a high pressure process; or (c) a heterogeneous copolymer of ethylene and one or more alpha-olefins having a density of less than 0.916 gram per cubic centimeter, a melt index of at least about 4 grams per 10 minutes, and a polydispersity greater than about 4.0, and, optionally, an organic peroxide; and
   (ii) co-extruding said formulations at a temperature no higher than about 160 degrees C.

2. The process defined in claim 1 wherein the homogeneous polyethylene is made with a metallocene catalyst.

3. The process defined in claim 2 wherein the homogeneous polyethylene is a copolymer of ethylene, one or more alpha-olefins, each having 3 to 8 carbon atoms, and, optionally, a diene, and has a melt index in the range of from 0.5 to 30 grams per 10 minutes.

4. The process defined in claim 1 wherein the outer layer polymer is a copolymer of ethylene and vinyl acetate or a methyl or ethyl acrylate or methacrylate wherein the unsaturated ester is present in an amount of from 15 to 38 percent by weight based on the weight of the copolymer, or an ethylene homopolymer.

5. A process for the co-extrusion of an inner layer around a conductive medium and an outer layer around the inner layer comprising:

   (i) introducing into an extruder adapted for profile co-extrusion, a conductive medium; an inner layer formulation comprising a homogeneous copolymer of ethylene, one or more alpha-olefins, each having 3 to 8 carbon atoms, and, optionally, a diene, said copolymer having been made with a metallocene catalyst, and having a polydispersity in the range of from 1.5 to 3.5, an essentially uniform comonomer distribution, and a melt index in the range of about 0.5 to about 30 grams per 10 minutes, and an organic peroxide; and an outer layer formulation comprising (a) a copolymer of ethylene and vinyl acetate or a methyl or ethyl acrylate or methacrylate wherein the unsaturated ester is present in an amount of from 15 to 38 percent by weight based on the weight of the copolymer; (b) an ethylene homopolymer having a polydispersity greater than about 4.5 and a density of at least 0.916 gram per cubic centimeter, said polymer made by a high pressure process; or (c) a heterogeneous copolymer of ethylene and one or more alpha-olefins , each alpha-olefin having 3 to 8 carbon atoms, said copolymer having a density of less than 0.916 gram per cubic centimeter, a melt index of at least about 4 grams per 10 minutes, and a polydispersity greater than about 4.5; and
   (ii) co-extruding said formulations at a temperature no higher than about 160 degrees C.

6. The process defined in claim 5 wherein the outer layer formulation contains an organic peroxide.

7. An article of manufacture comprising a conductive medium surrounded by a co-extrudate comprising a crosslinked inner layer of a homogeneous polyethylene having a polydispersity in the range of from 1.5 to 3.5 and an essentially uniform comonomer distribution and an outer layer comprising (a) a copolymer of ethylene and an unsaturated ester; (b) a polyethylene having a polydispersity greater than about 4.0 and a density of at least 0.916 gram per cubic centimeter, said polymer made by a high pressure process; or (c) a heterogeneous copolymer of ethylene and one or more alpha-olefins having a density of less than 0.916 gram per cubic centimeter, a melt index of at least about 4 grams per 10 minutes, and a polydispersity greater than about 4.0.

8. The article of manufacture defined in claim 7 wherein the polymer of the outer layer is crosslinked.

9. The article of manufacture defined in claim 7 wherein the homogeneous polyethylene is made with a metallocene catalyst.

10. The article of manufacture defined in claim 9 wherein the homogeneous polyethylene is a copolymer of ethylene,

one or more alpha-olefins, each having 3 to 8 carbon atoms, and, optionally, a diene, and has a melt index in the range of from 0.5 to 30 grams per 10 minutes.
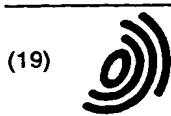
5

10

15

20

25

30

35

40

45

50

55

(54) **A process for extrusion**

(57)   A process for the co-extrusion of an inner layer around a conductive medium and an outer layer around the inner layer comprising:

(i) introducing into an extruder adapted for profile co-extrusion, a conductive medium; an inner layer formulation comprising a homogeneous polyethylene having a polydispersity in the range of about 1.5 to about 3.5 and an essentially uniform comonomer distribution, and an organic peroxide; and an outer layer formulation comprising (a) a copolymer of ethylene and an unsaturated ester; (b) a polyethylene having a polydispersity greater than about 4.0 and a density of at least 0.916 gram per cubic centimeter, said polymer made by a high pressure process; or (c) a heterogeneous copolymer of ethylene and one or more alpha-olefins having a density of less than 0.916 gram per cubic centimeter, a melt index of at least about 4 grams per 10 minutes, and a polydispersity greater than about 4.0, and, optionally, an organic peroxide; and
(ii) co-extruding said formulations at a temperature no higher than about 160 degrees C.

EP 0 743 161 A3

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 96 30 3510

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	WO 93 04486 A (EXXON CHEMICAL PATENTS INC.)	1-3,5-10	B29C47/02
	* page 14, paragraph 2 *		B29C47/06
Y	* page 24, paragraph 3; claims 1-3,7-10,19; figures 3,4 *	4	C08L23/04
	---		C08K5/14
			H01B7/02
Y	WO 86 03880 A (BP CHEMICALS LIMITED) * claims 1,2,7; figure 2; table 4 *	4	

P,X	DATABASE WPI Week 9604 Derwent Publications Ltd., London, GB; AN 96-030938 XP002043572 & CA 2 145 366 A (BICC CABLES CORP) , 25 September 1995 * abstract *	1-3,5	

A	WO 94 19168 A (EXXON CHEMICAL PATENTS INC.) * claims 1,6,7 *	1,5	
	---		TECHNICAL FIELDS SEARCHED (Int.Cl.6)
A	PATENT ABSTRACTS OF JAPAN vol. 9, no. 104 (C-279), 8 May 1985 & JP 59 232125 A (FURUKAWA DENKI KOGYO KK), 26 December 1984, * abstract *	1,3,5	B29C B32B H01B

A	DE 26 20 105 A (UNION CARBIDE CORP.) * claim 7; example 18 *	1,4,5	

A	US 3 852 518 A (BERNARD WARGOTZ ET AL) * claim 1 *	1,5,7	

A	US 4 587 039 A (NOBORU YAMAOKA ET AL) * claim 1 *	1	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	14 October 1997	Van Nieuwenhuize, O